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# THE CHARM SYSTEM

## DESIGN

BY

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THE MITRE CORPORATION

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ABSTRACT

CHARM is an exploratory investigation of techniques for proposed SAGE air traffic control integration. Flight plans, position reports, and other air movements data are transmitted by on-line teletype from the Boston ARTCC to the Whirlwind computer for processing and extrapolation. Flight plan positions are correlated with radar data by flight plan track monitors, corrected as necessary, and then transmitted to the ARTCC for a "clean" plan position presentation on a remote display console.

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## ILLUSTRATIONS

# CHAPTER 1 INTRODUCTION

## 1.1 PURPOSE

CHARM, an abbreviation for CAA High-Altitude Remote Monitor, is an exploratory effort by The MITRE Corporation in air traffic control and its integration and cooperation with air defense. CHARM's basic objectives are to test, evaluate, and demonstrate techniques and equipment which might in the future be incorporated in air traffic control or air defense systems. Two new techniques highlight CHARM's design: a manually operated teletype connected directly to the computer, with teletype acknowledgement to the operator; and transmission of a computer-generated display to a monitor console at a remote location over telephone data circuits.

## 1.2 BACKGROUND

The completion of the first SAGE system sectors, plus ever-growing requirements placed on the country's air traffic control system, have focused attention on the problems of coordinating and possibly integrating the two systems. Each has facilities and information that can help the other. For example, accurate, up-to-the-minute data on air movements from the air traffic control system is a prerequisite to proper identification by the air defense system. And radar and beacon data from the air defense system could supplement flight plan data in air traffic control. Planning for CHARM began in late January 1958. Detailed mathematical and operational specifications were completed in March 1958. They are documented separately. The writing and checkout of the computer program, which contains 19, 545 registers of instructions and data tables*, and installation of equipment needed for CHARM were completed late in 1958. The system has been operated on a twice-weekly basis since November 1958, and operations will continue through May 1959.

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*Summary information on the program preparation and checkout are presented in Lincoln Laboratory document 6M-5989, "CHARM Design and Implementation Effort," by D. R. Israel and J. W. Quigley (22 December 1958).

## 1.3 BASIC OPERATION (See Fig. 1-1)

Flight plans, position reports, and other air movements information are transmitted directly into the Whirlwind computer by the manually operated teletype at the High-Altitude Sector of the Boston Air Route Traffic Control Center (ARTCC). Flight plan information is then processed and displayed to flight plan track monitors, who use the displays of incoming radar data to correlate and correct flight plan positions. The Whirlwind computer encodes and transmits the resulting flight plan positions to the remote monitor console for display at the ARTCC as a supplement to the normal flight progress strips.

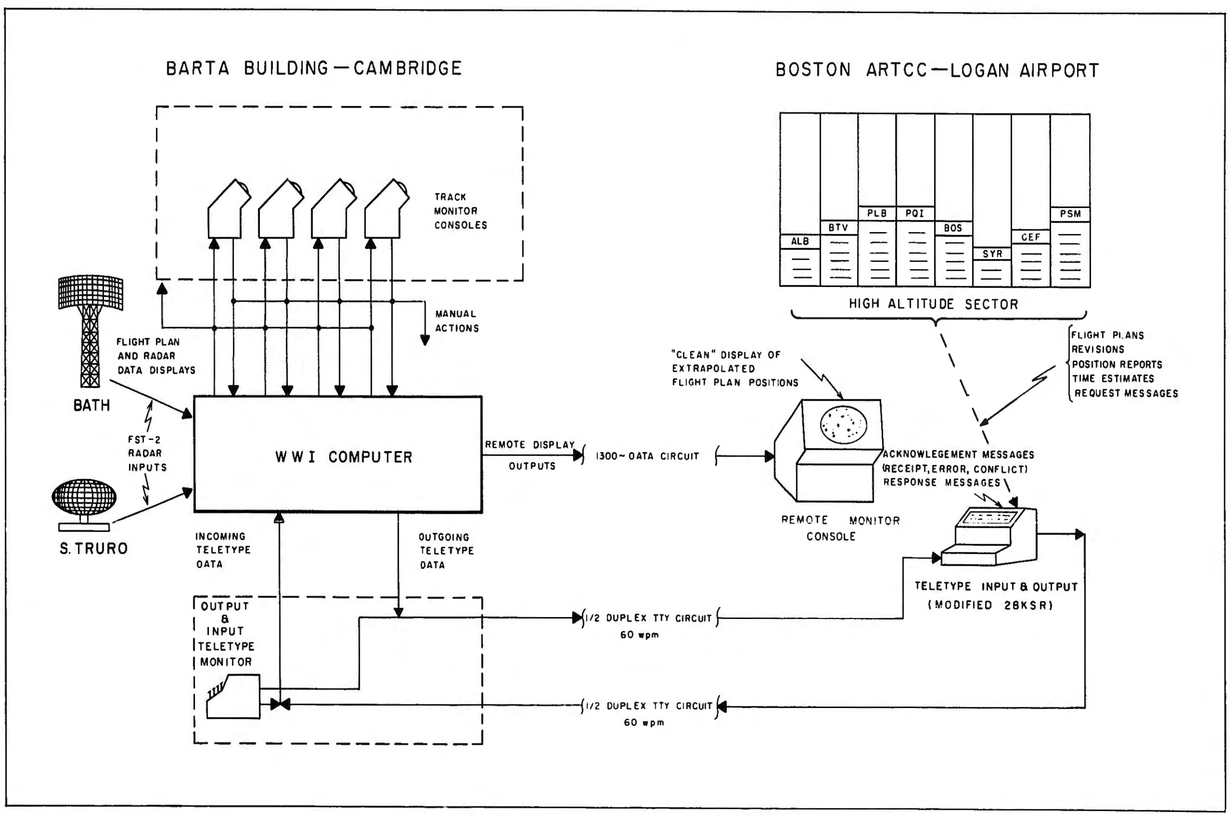


Fig. 1-1. Information flow for CHARM System.

## 1.4 AIMS AND LIMITATIONS

In keeping with its exploratory nature, CHARM was designed to be both flexible and expandable. Priority was given to designing a computer program that could be extended and to providing a sophisticated teletype input program which could handle a wider variety of messages than CHARM might initially require. Limited design and programming manpower, however, dictated the austere provisions for track monitoring, wind correction, and remote outputs.

## 1.5 OTHER DOCUMENTATION

CHARM operating results will be published in a forthcoming document, SR-5, "CHARM Operation and Test Results," by P. Stylos and W. S. Nicol (9 June 1959). The present document, which summarizes CHARM's key design features, replaces a document published in April 1958*. The earlier document was written before the computer programming was completed and therefore is not a fully accurate description. It also contains a description of experiments involving the Whirlwind and Cape Cod computer programs which were conducted to assist in designing CHARM, as well as a discussion of possible future extensions of the design. This material, somewhat out of date, has been omitted.

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*Lincoln Laboratory document 6M-5644, "Description of the CHARM System," by D. R. Israel, H. J. Kirshner, and P. Stylos (7 April 1958).

## CHAPTER 2 OPERATIONAL DESCRIPTION

### 2.1 SOURCE OF DATA

The High-Altitude Sector of the Boston ARTCC (See Fig. 2-1), source of flight plan data inputs for CHARM, is manned by two controllers and assistants. The sector is responsible for all aircraft above 24,000 feet throughout the entire Boston ARTCC area, bounded by the heavy line in Fig. 2-2. High-altitude traffic consists primarily of Strategic Air Command (SAC) aircraft. Also involved are smaller numbers of Navy, Air National Guard, other Air Force, and civil jet aircraft. High-altitude traffic control procedures and techniques presently employed at the ARTCC are essentially the same as those for low-altitude traffic, with flight plans broken down into progress strips and posted on progress boards. The high-altitude traffic differs, however, in being characterized by long flights with extensive flight plans; flights proceeding from point to point without using airways; flights with unspecified routes and long delays in warning areas or within a several-hundred-mile radius of geographic points; mission flights, in which streams of aircraft follow the same routes; and flights involving frequent and lengthy route revisions. Inputs to the High-Altitude Sector are primarily teletype and interphone messages from SAC bases, CAA communications stations, and adjacent ARTCCs, and voice radio communication with the in-flight aircraft.

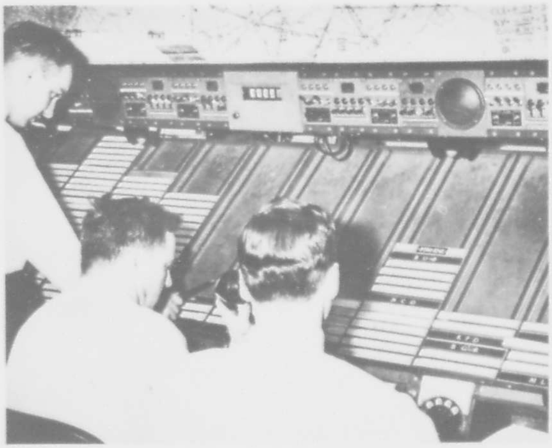

Fig. 2-1. High-altitude sector.

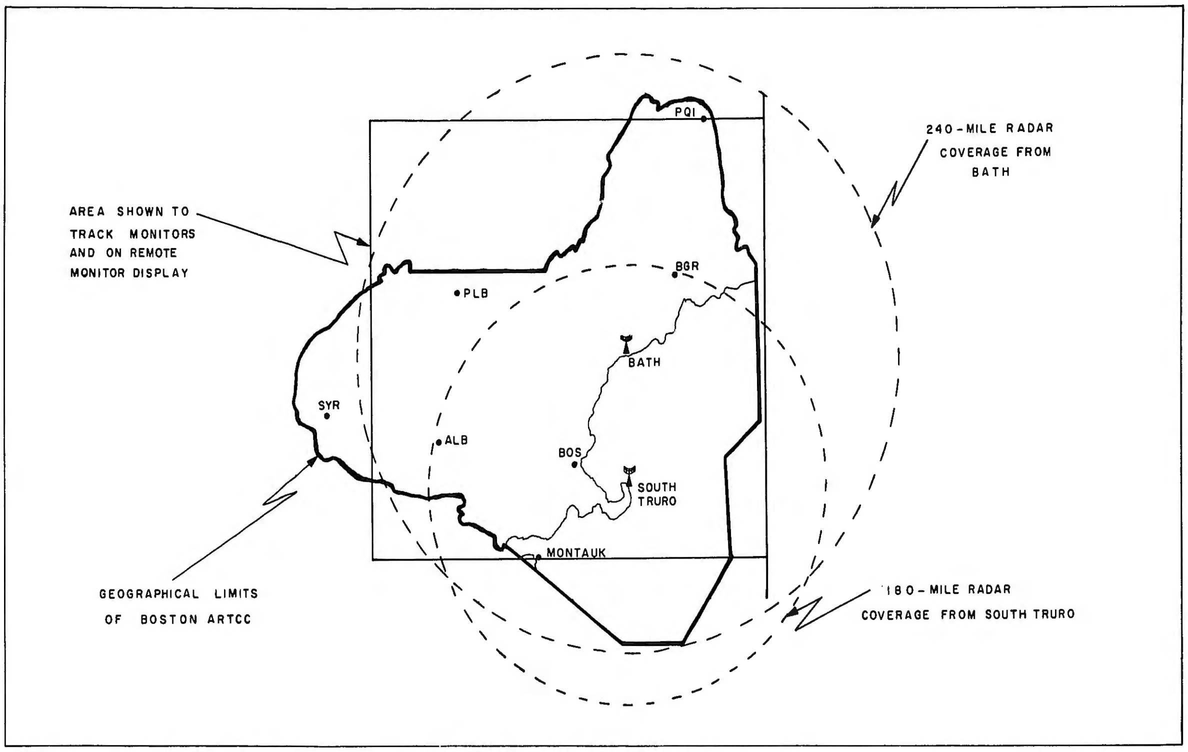


Fig. 2-2. CHARM geography.

## 2.2 TELETYPE INPUT TO THE COMPUTER

Data collected at the ARTCC is transmitted by a modified, keyboard-operated 28KSR teletype to the Whirlwind computer. The teletype produces page copy at the transmitting point and feeds directly into the computer over a one-half duplex, 60 word-per-minute circuit. The same machine also prints out for the operator the computer-generated responses to his input messages. A monitor machine (Fig. 2-3) is provided at the Barta Building in Cambridge, Mass. (where the Whirlwind computer and its terminal equipment are located), to produce page copy of data transmitted from the ARTCC. The incoming data is also fed to a typing reperforator unit (Teletype Corp. Model 14-P) in the Barta Building so tapes can be cut for testing. During program checkout, data can be fed into the computer from the keyboard of the monitor machine or from an associated tape transmitter-distributor (Teletype Corp. Model UA14).

Fig. 2-3. Teletype at the Barta Building. This modified 28 KSR is used for both input and output messages. A similar machine is located at the Boston ARTCC.

### 2.2.1 INPUT MESSAGE TYPES

The teletype input message types are:

a. Flight plans

b. Flight plan revisions and cancellations

c. Position reports

Such reports, including actual or estimated times, normally are accepted only if they refer to points on previously filed flight plans. Supplementary reporting points, however, may be used to give a position over a point not initially filed. Such reports can also be made when an aircraft leaves a warning area or is asked to report over a supplementary fix on an approach to an airport.

d. Code word routes

These are similar to flight plans except that they define a route that a number of later aircraft may follow. Any subsequent flight plan can use a previously filed code word to indicate its route and not have to specify it point-by-point again. Code word routes may also be used to designate commonly used departure paths from airports and airbases.

Each type of teletype input message is distinguished by an identifying character, content, and sequence. The design allows considerable flexibility, particularly in specifying flight plan routes in which fixes, positions related to fixes, latitude-longitude, airways, code word routes, and combinations of them may be used. Message content and sequence generally follow normal CAA/FAA practice, with standard abbreviations, location identifiers, and so forth. Examples are given in 3.1.

### 2.2.2 PRECAUTION AGAINST ERROR AND COMPUTER RESPONSES

To correct errors in the on-line typing of input messages, the teletype operator can make individual corrections or erase an entire message. The computer inspects incoming messages for errors in format and, in some cases, content. Following each input transmission, before proceeding with the next message, the operator must wait for an acknowledgement generated by the computer and printed out on his teletype. The acknowledgement may be a receipt message, indicating that it was accepted, an error message, stating that the computer has detected an error in the input, or a response to a request message (see below). If the computer generates an error message, the operator corrects the error. Otherwise he proceeds with the next message.

## 2.3 STORAGE AND UPDATING OF FLIGHT PLANS

CHARM handles data covering flights within and adjacent to the Boston ARTCC area, requiring the storage in the computer of information about the pertinent reporting points, navigation aids, airways and warning areas. With this information, each incoming flight plan, regardless of the form in which the route was filed, is decoded into a series of fixes, or geographic locations, for storage in the computer. For experimental convenience, the storage capacity of CHARM has been set at 24 flight plans, each of not more than 15 fixes. If a flight plan is filed with no starting time or only a proposed time, the plan will remain dormant until a teletype message is received containing a reported time for the first fix in the stored route. The computer then calculates estimated times of arrival for each subsequent fix along the route, using the filed flight plan speed and the stored information about the distances between fixes. Following activation of the flight plan, the calculated times of arrival over the fixes, or fix times, are continuously updated and corrected in accordance with position reports, speed changes, and flight plan revisions contained in subsequent teletype input messages. From these fix times, the current flight plan position can be determined at any time by interpolation, placing it between two fixes according to the distance between them and the elapsed time. This calculated position is used for both the track monitor and the remote display.

## 2.4 RADAR AND MARK X

Radar data inputs to CHARM come from the MITRE-operated AN/FPS-31 at Bath, Maine, and AN/FPS-20 at South Truro, Mass., both equipped with Mark X beacon interrogators. The coverage which can be expected from these radars on SAC-type aircraft operating at about 30,000 feet is shown in Fig. 2-2. Adequate coverage results, since almost all aircraft operating at high altitudes are responding to Mark X interrogations or are large aircraft giving good radar replies. Both search and Mark X data, as normally processed and transmitted over telephone circuits by AN/FST-2 equipment at Bath and South Truro, are received by Whirlwind, converted to a common coordinate system, and processed for display. Several past scans of incoming data are retained in computer storage for use in a radar history display.

## 2.5 TRACK MONITOR FUNCTIONS

Incoming radar data, stored radar data history, and current flight plan positions, calculated from flight plan messages and position reports, are displayed on four track monitor* consoles in a Barta Building operations room adjacent to the Whirlwind computer. The principal duties of these track monitors are to correlate the radar data with the present flight plan positions and make necessary corrections to the flight plan positions. In addition to the radar and flight plan position displays, the track monitors are shown key geographic points and selected flight plan routes. The area shown in the display, outlined in Fig. 2-2, is designed to take maximum advantage of radar coverage while providing the largest possible display scale. In performing his correlating, correcting, and tracking function (for radius and warning area flights), the track monitor uses a light gun and switch panels to communicate his intentions and data to the computer. These inputs supplement the stored flight plan data and supply corrections where needed. In the general case, and for those portions of a flight plan where an aircraft is proceeding directly from one point to another, the track monitor normally must make only minor speed or position corrections, since the flight plan position is generally reliable. In the case of radius or warning area flights, however, the monitors must use the radar data as the primary means of determining position. CHARM does <u>not</u> include a track-while-scan function, in which radar data is automatically processed to form radar tracks. Rather, CHARM extrapolates <u>flight plan tracks</u> derived from flight plans and makes the radar data available for manual corrections.

## 2.6 REMOTE MONITOR DISPLAY

The culmination of the flight plan processing and the action of the track monitors is the generation and transmission of a remote monitor display. This display is a plan position presentation of current and expected flight plan positions, corrected or modified by track monitors, over an area generally coincident with the geographic limits of the Boston ARTCC (see Fig. 2-2). The display supplements the flight progress strip postings used by the air

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*Hereafter referred to as track monitor or TM.

traffic controllers at the High-Altitude Sector. The remote monitor console installed in CHARM is a prototype designed by Group 63 of the Lincoln Laboratory (see Fig. 2-4). The traffic situation is displayed on a 21-inch direct-view storage tube employing a Charactron matrix. Tube characteristics permit a controlled image persistence of up to a few minutes, and daylight viewing is possible. For experimental convenience, transmission of data to the remote monitor console is by facilities and formats similar to those used for SAGE crosstell messages over 1300-bit-per-second telephone data circuits. Message transmission rate is such as to update the entire display of up to 24 flight plan positions once each minute.

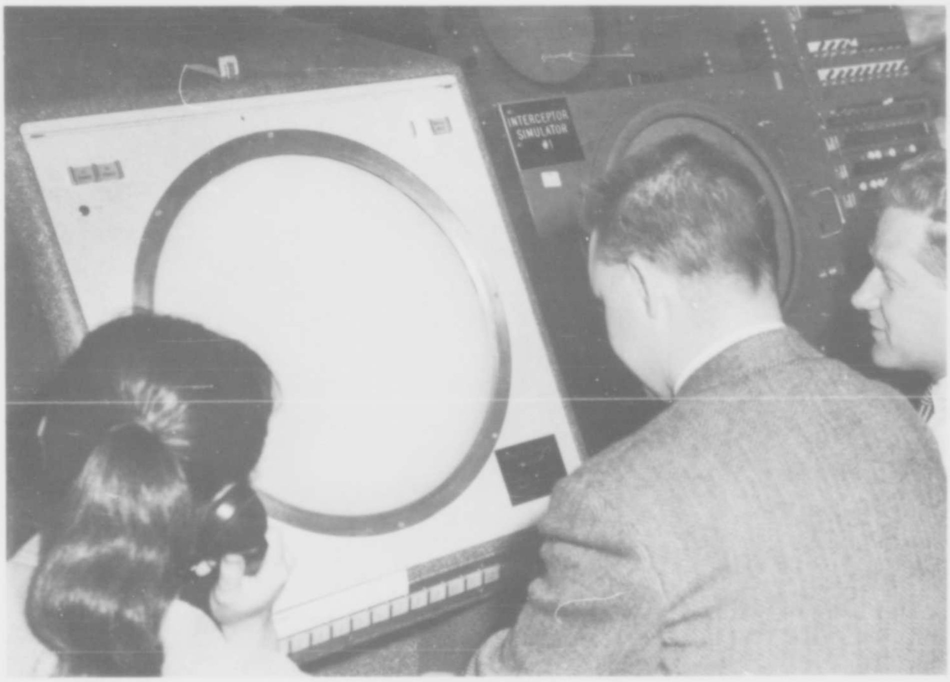



Fig. 2-4. Remote monitor display. The display is located at the Barta Building. The buttons below the display tube's face are for selecting categories.

## 2.7 OTHER OUTPUT MESSAGES

Two additional output teletype messages are provided for use by the traffic controller at the High-Altitude Sector. The first is a response message containing a statement of the present position of the aircraft with respect to its last fix and its expected time of arrival over the next fix. It is generated by the computer only upon request by a special input teletype position request message. The second output message is intended to indicate whenever a potential conflict exists. A conflict is here defined as a time separation of less than 10 minutes and altitude separation of less than 2,000 feet between flight plans. Conflicts will be detected only <u>over</u> specific geographic fixes. The feature is only a demonstration of a potential capability of a full conflict determination. A conflict message, specifying the fix and conflicting flight plans, will be generated by the computer whenever an input message contains information which indicates that such a conflict will exist.

An alternate mode of CHARM operation permits the generation of a third output message. In this mode, however, the conflict feature is omitted. The third message is the response to a special input message, and shows the correlation status, stored speed, route of flight by fixes, and the estimated time and altitude at each fix.

# CHAPTER 3 DESIGN FEATURES

## 3.1 TELETYPE INPUT AND OUTPUT

Although the current trend for remote keyboard input to computers is toward special-purpose message composers, it was felt that CHARM should investigate the possibility of using normal teletypewriters, coupled with provisions for error correction by the operator and error detection by the computer program. The size and complexity of the computer program for processing input teletype messages increase as more flexibility is permitted in message format and as the possibility of errors in the message increases. Message composers generally use fixed formats and include provisions which eliminate the possibilities of certain errors in the message preparation. The computer programs for processing such messages can thus be simpler. An objective of CHARM is to study the added programming complexity required by use of normal teletypewriters, particularly in view of their advantages of lower cost, availability, and flexibility in message types and formats.

CHARM uses a single teletype machine to transmit flight plans, position reports, and other information directly from the ARTCC to the computer and to receive output messages from the computer. The teletype input is connected on-line (i.e., no external buffering or human intervention) to a storage drum of the computer. The teletype output system of the computer is directly connected to the teletype equipment. Thus, ARTCC personnel have direct access into the computer by means of input teletype, and the computer communicates directly with ARTCC personnel by output teletype. For each message generated at the ARTCC and transmitted to Whirlwind, a reply is transmitted back to the ARTCC. The reply may take the form of a simple receipt, an error indication, a response to a request for information, or an indication of possible air traffic conflict created by the data just transmitted from the ARTCC.

### 3.1.1 INPUT MESSAGES

Teletype input messages consist of flight plans (F), flight plan revisions (R), position reports (P), code word routes (C), position request (J), and flight plan requests (Q). Messages begin with a prefix letter (F, R, P, C, J, or Q) and end with the character # . The body of the message consists of groups of characters separated by spaces or carriage returns. Input messages are not required to have fixed-length groups; padding or null characters are not required to insure that each character falls in a pre-assigned slot; and extra spaces, shifts, carriage returns, and line feeds are ignored and do not cause errors.

Flight plan messages, except for the prefix and terminating character, follow the format currently used by ARTCC's. Fig. 3-1 details the normal format of the message. Shown in Fig. 3-2 are the type of turn or en route points, airways, or code word routes that can be used to specify route of flight. The route, Group G in Fig. 3-1, can be specified by any combination of fixes, types of fixes, airways, or code word routes up to a maximum of 13 turn or reporting points (addition of the departure point and destination makes a total of 15).

| | MESSAGE SEQUENCE | UNITS | EXAMPLE |
|---|---|---|---|
| A. | IDENTIFYING PREFIX CHARACTER | | F |
| B. | AIRCRAFT IDENTIFICATION | 1-7 CHARACTERS | AJAX23 |
| C. | AIRCRAFT NUMBER AND TYPE | NUMBER: BLANK OR 1-99<br>TYPE: 1-5 CHARACTERS | 3/B47 |
| D. | TRUE AIRSPEED | KNOTS | 450 |
| E. | POINT OF DEPARTURE OR FIRST FIX | ANY FIX | BGR |
| F. | REQUESTED ALTITUDE | 100's OF FEET | 355 |
| G. | ROUTE | (See Route Specification, Fig. 3-2) | |
| H. | DESTINATION OR LAST FIX | ANY FIX | ALB |
| I. | TIME OF DEPARTURE | 24-HOUR CLOCK | P1344 |
| J. | MESSAGE TERMINATION CHARACTER | | # |

Fig. 3-1. Input teletype: flight plans. Groups A and J are program indicators to identify the type of message and indicate the end of the message. B gives the aircraft call sign in from one to seven alpha-numeric characters. Group C specifies the number (left blank if only one) and the type of aircraft, a / separating them. Group D gives true airspeed in knots. Groups E, G, and H specify the route (see below). Group I can list a proposed time (P), estimated (E) at the first fix, or departure time (D).

| | TYPE OF SPECIFICATION | EXAMPLE |
|---|---|---|
| A. | FIXES | BOS |
| B. | DISTANCE AND DIRECTION FROM FIX | 10W/BOS |
| C. | LATITUDE-LONGITUDE | 4310N/6703W |
| D. | RESTRICTED OR WARNING AREA (PLUS TIME) | W/518/1.30 |
| E. | RADIUS OF FIX (PLUS TIME) | 200R/BOS/1.45 |
| F. | AIRWAYS | |
| | LOW FREQUENCY (LF-MF) | A7 |
| | VICTOR (VOR) | V13E |
| | JET | J21T |
| | CONTROL AREA | C1205 |
| G. | CODE WORD ROUTE | CEFDEP |
| H. | COMBINATIONS OF A-G | BOS A7 V24 BTV 100R/CEF/2.0 |

Fig. 3-2. Input teletype: route specification.

Flight plan revision messages permit revision of aircraft identity, type, flight size, speed, altitude, route and/or proposed departure time. The format roughly follows that of a flight plan message. Each group to be revised is indicated by a code letter identifying the group. The correct information for the group being revised is then typed in accordance with the flight plan input format. A revision message may also be used to cancel a flight plan. Fig. 3-3 shows the format for revision messages and an example of flight plan revision. In the example AF21623 has changed its altitude to 32, 500 feet and its proposed departure time to 1221.

| FLIGHT PLAN REVISION-SEQUENCE |
| --- |
| A. PREFIX CHARACTER<br>B. AIRCRAFT IDENTIFICATION<br>C. REVISION ITEM PREFIX<br>1. I = AIRCRAFT IDENT.<br>2. Y = FLIGHT SIZE/TYPE<br>3. S = TRUE AIRSPEED<br>4. A = ALTITUDE<br>5. U = ROUTE<br>6. M = TIME ACTIVE<br>D. REVISION<br>E. TERMINATION CHARACTER<br><br>EXAMPLE:<br>R AF21623 A 325 M P1221 # |

Fig. 3-3. Input teletype: flight plan revision messages.

Position reports are used to report progress along the aircraft' s intended route. Generally a position report consists of a statement of the actual time over a fix and an estimated time over the next fix (a position report may also be used to amend -- not revise -- the filed flight plan by redesignating a filed fix as a hold fix). Normally, fixes used in position reports are those specified in the flight plan or derived by the program from compulsory airways reporting points. Other points -- supplementary reporting points -- are accepted provided a succeeding fix on the flight plan or the next compulsory point is also specified. The format for the position report message and some examples are shown in Fig. 3-4. Note that items which are not available for transmission may be omitted.

| MESSAGE SEQUENCE | |
|---|---|
| 1. | IDENTIFYING PREFIX LETTER (P) |
| 2. | AIRCRAFT IDENTIFICATION |
| 3. | FIX |
| 4. | TIME AT FIX (OR HOLD) |
| 5. | ALTITUDE |
| 6. | TIME ESTIMATE AT NEXT FIX |
| 7. | NEXT FIX |
| 8. | TERMINATION CHARACTER (# ) |

EXAMPLES

A. P AF90967 PVD 1204 VFR E1211 BOS #

B. P AJAX21 ALB 1423 125 #

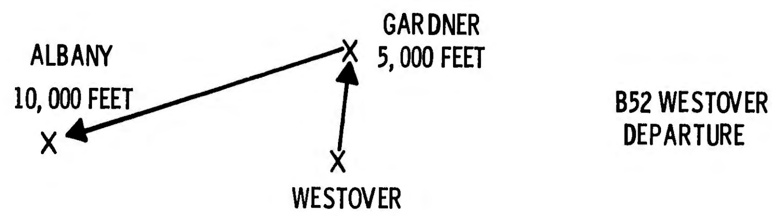
C. P V2250 E1239 BOS #

D. P UAL333 295 #

E. P PONYRED BTV H #

Fig. 3-4. Input teletype: position reports. Example A shows a normal position report message. In B, data pertaining to the next fix has been omitted. Example C omits the current fix. D shows that UAL333 is maintaining an altitude of 29,500 feet. Example E is a special type of report indicating that the aircraft has been requested to hold en route at Burlington (BTV).

Code word route messages are identical in format to a flight plan, except that aircraft type, flight size, airspeed, and departure time are omitted. Such messages may be used to describe the intended path to be followed by aircraft for which flight plans will be filed later. The code word routes may describe departure patterns, altitude reservations, refueling area routes, etc. When the flight plan is later filed, the code word route identification may be used in the flight plan in a manner similar to that in which airways are used. Fig. 3-5 shows the filing and use of code word routes.




FILED: C CEFDEP CEF GDM 50 ALB 100 0.15 #

USED: F SMOBLUE 3/B52 440 CEFDEP BTV RKD 310/330 UL CEF 1403Z #

OTHER USES:

PREFERENTIAL ROUTES
REFUELING ROUTES
SAC MISSION FLIGHTS
TEMPORARY AIRWAY REROUTING

Fig. 3-5. Code word routes.

Request messages permit the operator at the ARTCC to request information from the computer. The two types of request message are position request (prefix J) and flight plan information (prefix Q).* The format for each is the prefix character followed by the aircraft identification and message termination character. The computer-generated response to these messages is discussed in Section 3.1.4.

### 3.1.2 ERROR CORRECTION

The remote keyboard input equipment for CHARM is a teletypewriter at the ARTCC. Error correction facility is provided to the operator by allowing him to back up one group with the character X (or /). For example, if the operator intends to type the group BOS, but instead types BPS, the error may be corrected by the operator, as in the following sequence:

CEF BED BPS X BOS

If the error were further back in the text -- for example, if BFD were mistakenly typed instead of BED -- the correcting sequence would read:

CEF BFD BOS X X BED BOS

If the operator decides that he has made several errors and that corrections are best made by retyping the message from the start, he may cancel the entire message by sending the group XXX if he has not sent the terminating character #. If the operator decides that the message as transmitted appears correct, sending the terminating character # will cause the computer to process the message.

---

*As noted earlier, the flight plan information (Q message) feature cannot be used, due to storage requirements, at the same time as the conflict messages.

### 3.1.3 ERROR DETECTION

Some errors will elude detection or correction by teletype operators. To guard against them, all input teletype messages are checked by the computer to determine whether they contain errors from typing, procedure, or transmission. The teletype operator then is informed whether his message is accepted or whether it contains an error. If an error is detected in an input message, the entire message is not voided. The portion of the message up to the error is saved and the operator is given the option of retransmitting the remainder of the message or canceling the saved portion and sending the entire message. For example, suppose the following flight plan were filed:

F AJAX10 B47 CEF VFR ALB 100R/PLB/2.00 CEF D1620#

Note that the aircraft speed has been omitted and that this does not comply with the input flight plan message format. The computer will generate an error message indicating that the computer processed information only up to the group B47. The operator must then put in the speed, point of departure, route of flight, destination and departure time. The type of error checks depends upon the message type and upon the particular item in a message. For example, the aircraft identification in a position report or a flight plan revision message is checked to see whether a flight plan with the same aircraft identification has been previously filed. If no such flight exists, an error message will be generated. The aircraft identification of a flight plan message is checked to make certain that it has not been previously filed. Two flight plans with the same identification can't exist. In general, routes are checked for coherence. For example, if a number of airways are filed to define a route, successive airways must intersect. Format is checked to determine that storage capacity is not exceeded for certain items. Aircraft identification may not exceed seven characters, aircraft type five characters, altitude three digits, etc. Logical checks are also performed. For example, time sent in messages is checked to see that it does not exceed the number of hours and minutes in a 24-hour clock (2359) and that it is not later than the present time (unless it is tagged as Proposed or Estimated).

### 3.1.4 OUTPUT MESSAGES

#### 3.1.4.1 ACKNOWLEDGEMENT

Acknowledgement messages are of two kinds: receipt and error. A receipt message indicates that the transmitted data has been accepted and stored. An error message indicates that an error has been detected and where it occurred. A conflict message may accompany a receipt message and indicates that the message just accepted has created a possible air traffic conflict. It will also indicate the location of the possible conflict and the other aircraft involved. Bell signals are sounded and printed to alert the operator for acknowledgement messages. A single bell accompanies a receipt message, two bells call attention to an error message, and three bells advise of a conflict message. The following sequence illustrates the format and use of acknowledgement messages. Assume an operator types the following message:

F NIMIO B52 425 BOS VFR PIQ 1225 #

It is noted that the operator typed PIQ rather than PQI for Presque Isle. The computer then generates the error message:

ALB #

This means the computer program processed the input message up to ALB and could not identify the fix PIQ. The operator must then complete the message correctly as follows:

PQI 1225 #

The computer then generates the receipt message:

F NIMIO 07 #

Thus the flight plan for NIMIO has been accepted and assigned data reference number 07. Suppose that the flight plan conflicted with a previously filed flight plan. The receipt would then be

F NIMIO 07
ALB AJAX18 #

The indication now is that NIMIO is in potential conflict with AJAX18 over ALB. The criterion for conflict is a flight plan time separation of 10 minutes or less and an altitude separation of 2,000 feet or less, or one aircraft is VFR.

3.1.4.2 RESPONSE

Response messages are output teletype messages sent to the ARTCC when an error-free input request message is received. The response to a position request message consists of the aircraft identity, radar correlation status (U or C), present position (in terms of distance and direction from previous fix), present time, time estimate at next fix, and the next fix. If the following position request message were transmitted to the computer:

J NIMIO #

the computer might generate the response

NIMIO U 24W/BOS 1233 E1259 ALB #

This message indicates that NIMIO is uncorrelated and is 24 (nautical) miles west of Boston at 1233. The estimated time at Albany is 1259. To illustrate the flight plan information request message, consider the following flight plan to have been filed:

F AF4395 T33 375 BOS VFR ALB PQI UL PLB 1200 #

To receive the flight plan information message, the following request message is typed:

Q AF4395 #

The computer then generates the response:

| | | |
|---|---|---|
| AF4395 | C | 375 |
| 1200 | BOS | VFR |
| E1230 | ALB | VFR |
| E1335 | PQI | VFR |

| | | |
|---|---|---|
| E1424 | UL | VFR |
| E1433 | PLB | VFR # |

The response shows that AF4395 is correlated, the computer program speed is 375 knots, and the aircraft was over Boston flying VFR, at 1200 hours. The computer-generated estimates for all succeeding fixes are given.

## 3.2 COORDINATE SYSTEM AND GEOGRAPHICAL DATA STORAGE

The computer stores and processes all positional information in an x, y coordinate plane tangent to the earth and aligned with true north at a center of coordinates of 44°00' N, 71° 00' W -- located about 50 miles west of Bath, Maine. All stored geographic information is derived from positions projected onto this x, y plane in a stereograph-like projection. Incoming radar data is projected and converted from R, Θ to x, y in the computational plane. Radar site locations and orientation corrections are appropriately introduced to account for the method of projection. The x, y coordinate plane and stored values of x, y positions extend ±512 miles about the center of coordinates. This coverage completely encloses the Boston ARTCC limits and permits the handling of flights entering and leaving the Boston ARTCC area. (As noted in Sections 3.4 and 3.6, a smaller area is used for the track monitor and remote monitor displays.)

The computer stores the locations of 225 geographic points and fixes within and adjacent to the Boston ARTCC area. These include positions of navigation aids -- VOR, LF-MF range stations, radio beacons, and outer markers -- and reporting points. For each of these fixes, the two-, three-, or four-letter* location identifier and the x, y coordinates are stored in fix data storage. Thus, given a location identifier in a teletype input message, the computer scans through fix data storage to determine the associated position coordinates. Some flight plans will specify fixes in terms of latitude and longitude or in terms of warning areas. The identification and geographic center of the warning areas are stored in the program in teletype code and in x, y coordinates respectively. The computer program translates latitude and longitude to x, y coordinates.

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*There are times when a three-letter fix is used to specify both the geographic locations of a fix and some navaid associated with that fix. The locations may differ by as much as 5 or 10 miles. To resolve this ambiguity, a four-letter identifier is arbitrarily assigned for the navaid associated with the fix.

Flight plans may specify routes containing one or more airways. These may be high-altitude jet airways, Victor (VOR) airways, colored (LF-MF) airways, or control areas. In each case, the computer has stored the sequence of fixes which defines each airway in airways data storage. Thus, for airways specified in a teletype input message, the computer can ascertain the sequence of fixes from airways data storage and the location of each fix from fix data storage. If a flight plan contains the route specification airway-airway (J55V J16V), the program extracts the fixes along both airways. The fixes are compared in order to determine the intersection point. This point is designated the termination fix along the first airway and the initial fix along the second airway. This comparison procedure also determines the direction of flight.

## 3.3 FLIGHT PLAN STORAGE, FIX TIME CALCULATIONS, AND EXTRAPOLATION

Twenty-four blocks of registers are reserved in the computer program for storing flight plan information. To avoid too frequent repetition of the same track number, on alternate uses of a block the track number is increased by 30 (octal) over the block number. Thus, for example, the second, fourth, sixth, etc., use of block 24 will yield a track number of 54. Each block of flight plan data storage is divided into two parts. One contains all of the general information on the flight plan -- flight designation, type and number of aircraft, speed, etc. -- and information on current status and position. The second part contains the route of flight broken down into specific fixes. Each flight plan block contains space for 15 fixes. For each fix, the computer stores the fix identity, the altitude over the fix, and later, the estimated time over the fix. Many flight plans do not specify a flight directly to a fix, but rather to a point at a given distance and direction from the fix, as for example, a point 10 miles west of Boston. The computer stores this distance and direction.

When a flight plan message is first received, it is broken down into the proper sequence of fixes as described in Section 3.2 As information is stored (for each fix), the <u>type of fix</u> is determined and stored. The types of fixes and their significance are:

D Fix

> A flight plan track is expected to fly directly to the position associated with a D fix and then to depart immediately toward the next fix.

R Fix

Warning area fixes, restricted area fixes, or fixes about which a radius flight is proposed are marked as R fixes. Flight plan tracks are not generally expected to approach directly to these fixes, but rather to fly in the vicinity of the fix for some time before proceeding towards the next fix.

H Fix

Any fix specified for a Hold in the flight plan, or revision thereof, is marked as an H fix. Flight plan tracks are expected to approach an H fix directly and then to hold close proximity to that location.

Filed flight plans remain inactive until a position report or other message specifies an actual time of arrival or passage over the first fix. When this occurs, this time will be stored with the fix in the flight plan storage block, and the flight plan speed will be used to compute estimated times over succeeding fixes. If

$T_A$ is the time over fix A

$X_A$, $Y_A$ are the coordinates of fix A

$X_B$, $Y_B$ are the coordinates of the next fix B, and

S is the stored flight plan speed,

then

$$T_B = T_A + \frac{1}{S} \left\{ (X_B - X_A)^2 + (Y_B - Y_A)^2 \right\}^{1/2} \qquad \text{Equation 1}$$

Wind information is not used in these calculations.

Either as a result of a deliberate specification in the flight plan or as a result of incorporating a previously-filed code word route, certain fixes as the start of a flight plan may be marked as departure delay fixes. The calculated times between these fixes will be increased over that which would be obtained by using the stored flight plan speed, with the intention of approximating the lowered forward speed while an aircraft is climbing.

The calculations of fix times, as described above, are normally carried out from the first fix through the first R or H fix. Time calculations beyond an R or H fix are not made until a position report or other message specifies an actual or estimated time for the first fix beyond that R or H fix; when this is done, fix time calculations are made ahead to the next R or H fix, or the end of the flight plan. As position reports containing actual or estimated times over fixes are received, the corresponding fix times are changed, and all succeeding fix times along the flight plan route are corrected appropriately. If an aircraft, for example, reports a time over fix B which is four minutes earlier than the previously calculated and stored time for B, the new time is stored for B and all succeeding fix times are changed four minutes. Every six seconds after a flight plan is activated, the computer determines the aircraft's new position in the flight plan. In the general case, the computer first compares the present time, T, with the stored fix times. If two successive fixes, A and B, are found such that $T_A \leq T \quad T_B$, then the present X and Y velocity components are found from:

$$\dot{X}_P = \frac{X_B - X_A}{T_B - T_A} \qquad \text{Equation 2}$$

$$\dot{Y}_P = \frac{Y_B - Y_A}{T_B - T_A} \qquad \text{Equation 3}$$

In the case of a command heading when the flight plan is proceeding at an angle $\Theta_P$ to the x axis,

$$\dot{X}_P = S \cos \Theta_P \qquad \text{Equation 4}$$

$$\dot{Y}_P = S \sin \Theta_P \qquad \text{Equation 5}$$

where S is the stored flight plan speed. In the event that at time T it is found that $T \geq T_B$ where fix B is an R or H fix and no times have been calculated for subsequent fixes, the present position will be the same as fix B, with $\dot{X}_P$ and $\dot{Y}_P$ set equal to zero. Every six seconds when $\dot{X}_P$ and $\dot{Y}_P$ are calculated, the new present position is determined from

$$X_P = X_A + \dot{X}_P (T - T_A) \qquad \text{Equation 6}$$

$$Y_P = Y_A + \dot{Y}_P (T - T_A)$$

When light gun action is used, the latest position is obtained from

$$X_P = X_L + \dot{X}_P \ (T - T_L) \qquad \text{Equation 8}$$

$$Y_P = Y_L + \dot{Y}_P \ (T - T_L) \qquad \text{Equation 9}$$

where $(X_L, Y_L)$ is the light gun radar data position as defined at time $T_L$. The specific rules for determining present position and velocity components depend upon the value of an extrapolation status which is normally set by the characteristics of the stored flight plan, but which can be altered or affected by track monitor actions. The settings of the extrapolation status and their significance as regards determination of position are:

Status D (direct) indicates normal extrapolation to a next D or H fix from a previous fix. Equations 1-3 and 6, 7 are used.

Status R (radius) indicates that the next fix is an R fix. Equations 1-3, and 6, 7 are used.

Status H (hold) indicates that the flight plan is at an H fix, with no times calculated or available for succeeding fixes. $X_P$ and $Y_P$ are set equal to the coordinates of the H fix; $\dot{X}_P$ and $\dot{Y}_P$ are set equal to zero.

Status S (suspend) indicates that the flight plan is at an R fix, with no times calculated or available for succeeding fixes. $X_P$ and $Y_P$ are set equal to the coordinates of the R fix; $\dot{X}_P$ and $\dot{Y}_P$ are set equal to zero.

Status L (light gun) occurs as a result of a track monitor action (see Section 3.4) and indicates that the flight plan is being extrapolated from a radar data-light gun position to the next D or H fix. Equations 8 and 9 are used.

Status C (command) occurs as a result of a track monitor action (see Section 3.4) and indicates that the flight plan is being extrapolated from a light gun position along a command heading. The value of command heading is used for $\Theta$

in Equations 4 and 5, and the resultant $\dot{X}_P$ and $\dot{Y}_P$ are used to calculate $X_P$ and $Y_P$ in Equations 8 and 9.

Status F (freeze) occurs as a result of a track monitor action and indicates that flight plan extrapolation has been stopped. Present position remains unchanged from whatever it was when the action was taken; $\dot{X}_P$ and $Y_P$ are set to zero.

## 3.4 TRACK MONITOR ACTIONS AND DISPLAYS

The function of the track monitor (TM) positions in CHARM is to monitor computer displays showing the extrapolated or "present" flight plan positions together with the radar data from the South Truro and Bath sites and to make any needed correlations and corrections of flight plan positions. The correlation, or identification, of corresponding radar data returns and flight plan positions is based on judgment of the track monitor regarding the proximity of the data, the direction of flight, the past and future flight plan route, and in some cases, the type of radar return -- search or Mark X. The correction of the flight plan data is possible as a result of the accuracy and timeliness of the radar data. The actions of the track monitor are intended to enhance the flight plan data; if no actions are taken, the flight plan remains unchanged. Four identical TM positions are provided to handle up to 24 flight plans. Assignment of flight plans to monitors is by SOP, on an area basis. At each position, the following displays are available:

a. Flight plan track display
b. Flight plan route
c. Present search radar data
d. Search radar data history
e. Mark X radar data
f. Mark X radar data history
g. Selected geographic points.

The facilities available for TM actions at each of the four positions are:

a. A light gun, for use on present radar data displays
b. A nine-button action switch panel

c. Two eight-button track number (TN) switch panels

d. A four-button increment switch panel

e. An eight-position rotary heading switch panel

f. An activate push-button with indicator light.

A diagram of the TM switch panels is shown in Fig. 3-6. Examples of displays illustrating possible situations confronting a TM are shown in Figs. 3-7, 3-8, and 3-9, together with the actions taken and resultant effects. Whenever a TM takes an action, he must select an action switch and set the track number, heading, and increment switches to the desired values. He must then use the activate button or light gun, depending on the action desired, to signal the computer to execute the action. The nature of the nine TM actions is summarized below. Unless otherwise specified, use of the activate button is implied.

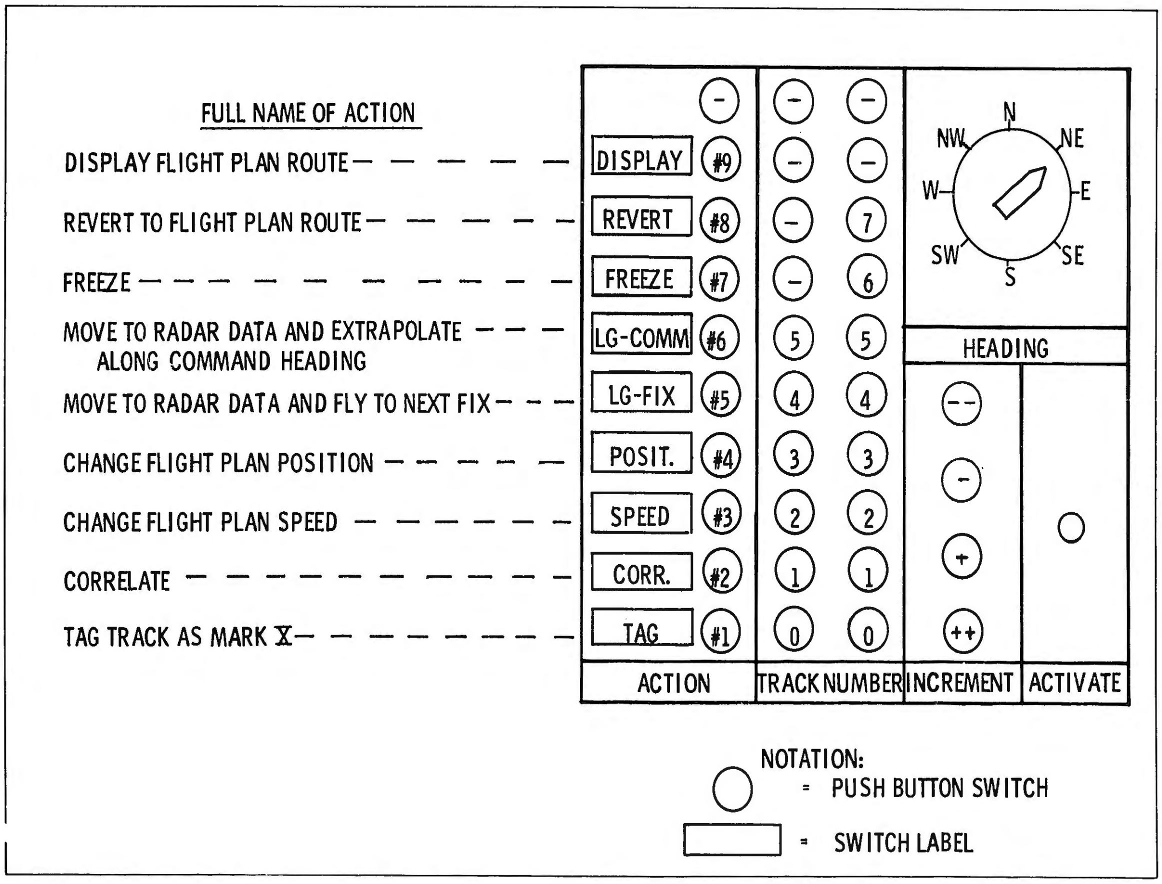


Fig. 3-6. Track monitor switch panel.

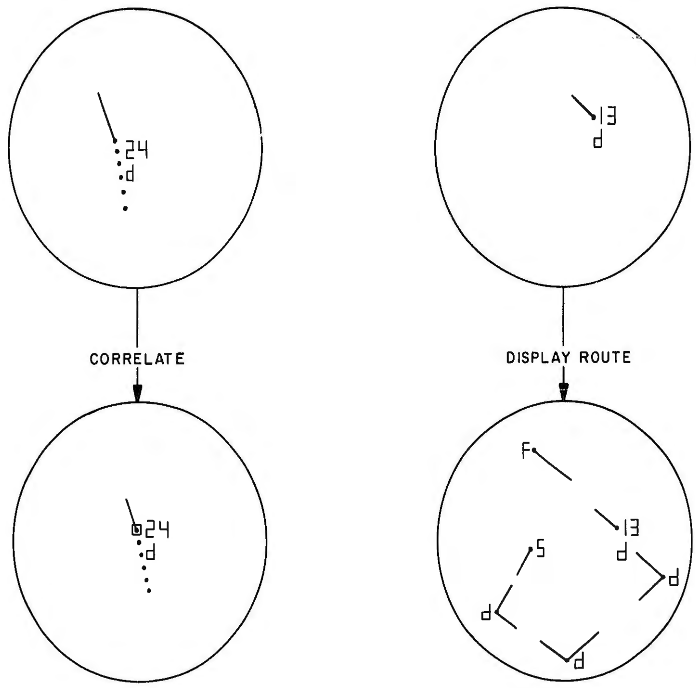


Fig. 3-7. Track monitor actions.

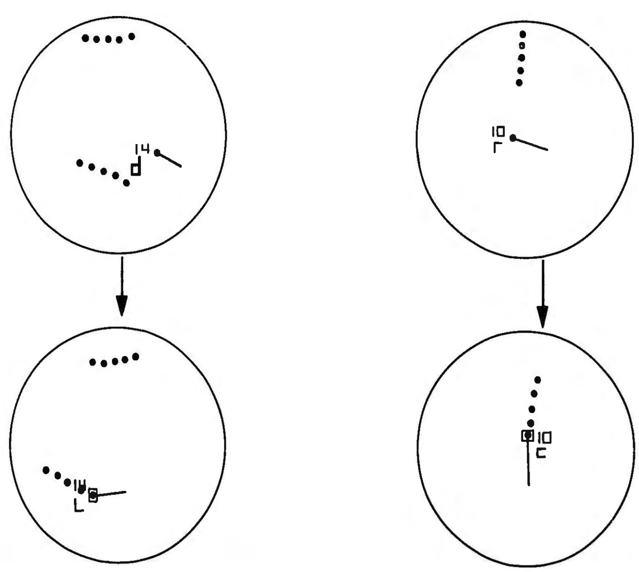

Fig. 3-8. Extrapolation status. Track monitor can change extrapolation status by light gun action.

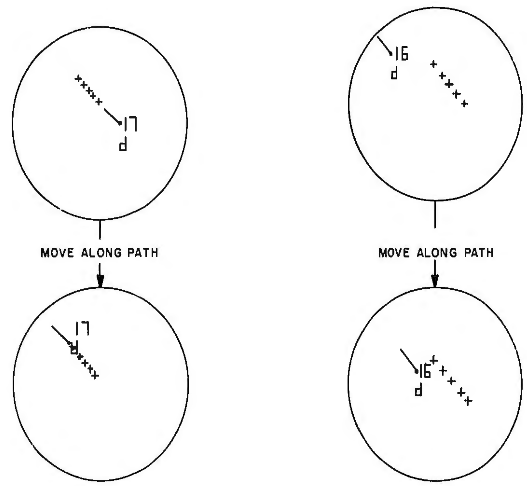


Fig. 3-9. Track monitor actions.

Action # 1: TAG TRACK AS MARK X

Used with TN switches. Action indicates that the flight plan track is replying to Mark X interrogations. Action causes a special display for this flight plan for use in future correlation with Mark X data. The next use of this action for same flight plan will remove the special display.

Action # 2: CORRELATE

Used with TN switches. Action indicates that correlating radar (search or Mark X) data is close to the flight plan track. Action causes a special correlation display for the flight plan track.

Action # 3: CHANGE FLIGHT PLAN SPEED

Used with TN and increment switches. Action causes an incremental change in stored flight plan speed, and thus should move the "present" flight plan position. Correspondence of labels on switches to speed changes will be: ++ = +50 knots, + = +10 knots, - = -10 knots, -- = -50 knots. Larger speed changes are obtained through repeated use of the switches.

Action # 4: CHANGE FLIGHT PLAN POSITION

Used with TN and increment switches. Action causes incremental change in calculated fix times, and thus may change the "present" flight plan position. Correspondence of labels on switches to time changes will be: ++ = +5 minutes, + = +1 minute, - = -1 minute, -- = -5 minutes. Larger time changes can be obtained through repeated use of the switches. This action can be taken only when the extrapolation status is D or R.

Action # 5: MOVE TO RADAR DATA AND FLY TO NEXT FIX

Used with TN switches and light gun set over radar data. Action causes present flight plan position to be moved to radar data location; flight plan will then be flown to next fix along route. This action should be taken only for flight plans having an extrapolation status of D (direct) or L (light gun), that is, for flight plans proceeding directly to the next fix. The action will change extrapolation status to L.

Action # 6: MOVE TO RADAR DATA AND EXTRAPOLATE ALONG COMMAND HEADING

Used with TN and HEADING switches and light gun set over radar data. Action causes present flight plan position to be moved to radar data location; flight plan will then be extrapolated along given heading with stored flight plan speed. This action should only be taken for flight plans whose extrapolation status is not D or L; action will change status to C.

Action # 7: FREEZE

Used with TN switches. The action, which can only be taken when flight plan has an extrapolation status of C, causes cessation of flight plan extrapolation or movement and sets the extrapolation status to F.

Action # 8: REVERT TO FLIGHT PLAN

Used with TN switches. Action voids current effects of actions #2, 4, 5, 6, or 7 but does not revert actions #1, 9 nor does it revert action #3, CHANGE FLIGHT PLAN SPEED.

Action # 9: DISPLAY-FLIGHT PLAN ROUTE

Used with TN switches. Action causes a display of the entire flight plan route. The display, if not removed by asking for a display on a different flight plan, can be removed by another use of this action.

In general, it is desired that the track monitor move a flight plan track to the correlating radar data by means of position changes (Action # 4), followed if necessary by speed changes (Action # 3) before using the light gun actions ( #5 and #6). Certain TM actions are "illegal" if taken on flight plan tracks having specified values of extrapolation status. These actions will be ignored by the computer. The flight plan track display shows the present position of activated flight plan tracks as a point, vector, and symbology for each flight plan. Examples are shown in Fig. 3-10 and 3-11. The "present" position is marked by a point. A small square encloses the point whenever the flight plan has been correlated. Heading and speed are shown as a vector proceeding from the point. Vector length is equivalent to two minutes of travel, except that no vector is shown for a track with an extrapolation status of H, S, or F. Two parallel vectors are used whenever the track is tagged as Mark X. Track symbology consists of two lines of two characters each, placed to the left or right of the point and vector, depending upon direction of flight. The top line of the symbology shows the track number displayed as two octal digits from 00 to 57. Extrapolation status is shown as a single letter at the left of the second line of the symbology as follows:

 (direct) indicates normal extrapolation to the next fix from a previous fix.

 (radius) indicates that the next fix is a radius, warning area, or restricted area fix, and that the flight plan should be extrapolated towards the fix, although it cannot generally be expected to fly directly to the fix.

h (hold) indicates that the flight plan is positioned at HOLD fix, and will not be extrapolated further until a teletype input message regarding the next fix is received.

S (suspend) indicates that the flight plan is positioned at a radius, warning area, or restricted area fix and will not be extrapolated further until receipt of a teletype input message.

L (light gun) indicates that the flight plan is being extrapolated from a light gun-radar data position directly to the next fix.

C (command) indicates that the flight plan is being extrapolated from a light gun-radar data position along an inserted command heading.

F (freeze) indicates that the flight plan extrapolation has been suspended as a result of TM action.

A flight size greater than one is shown on the right of the second line of the symbology. A flight size of one is not displayed. Whenever a flight plan track is between two fixes which have been marked for departure delay, a third line of symbology is shown as: d d

Figure 3-10 shows the makeup of the flight plan message.

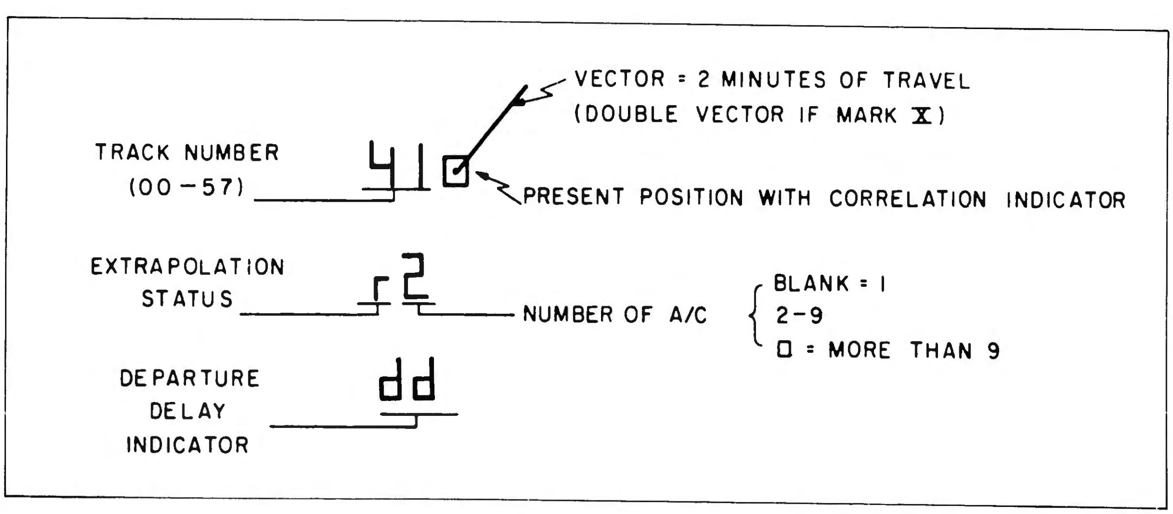


Fig. 3-10. Track monitor displays: flight plan symbology.

Track monitor use of Action #9, DISPLAY FLIGHT PLAN ROUTE, causes a display of the flight plan route as a series of straight-line segments. Any R or H fix along the route is marked with an r or h. Fig. 3-11 shows an example of a route display. Each TM may request only one such display at a time. It will remain until a display for another flight plan is requested or until Action # 9 is used again with the same flight plan track number. The route display requested by a TM is shown only to him, but each TM may request a route display on the same flight plan. Two separate displays of radar data are made, one showing the current radar data, the other showing a short-term history. All displays of radar data show search radar returns as points and Mark X returns as small crosses (+). The current radar data display is made each six seconds and shows all radar data received in the past 12 seconds. The radar history display is made each six seconds and shows all radar data received during the previous four even-numbered 12-second intervals. The geography display shows 13 fixes or geographic locations, with storage provided for up to 11 additional locations. Each fix is displayed as a small square at the location, with two or three characters below the square giving the location identifier. In general, all displays are updated

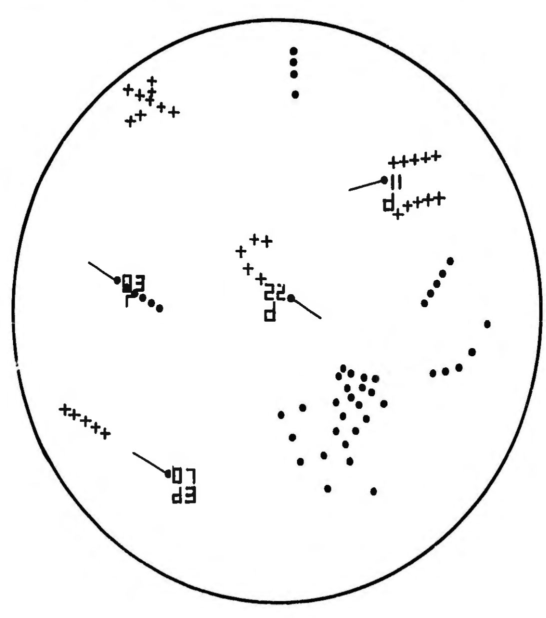

Fig. 3-11. Typical track monitor display. Shown are flight plan position, Mark X and search radar tracks, and search clutter. Tracks 11, 22, and 7 are on direct flights. Track 3 is in a radius flight.

and presented each six seconds. The area of display is as shown in Fig. 2-2, with no flight plan tracks, routes, radar data or geography shown outside of a 360-mile square centered at 44°N, 71°W. Fig. 3-12 shows two TM positions during system operations.


Fig. 3-12. Track monitors and consoles. Two of the four TM positions are shown. Note the wing panels, housing display selection switches (along the top and bottom) and action switches (center). Both TMs are taking light gun actions.

## 3.5 CONFLICT SEARCH

All activated flight plans are screened to determine whether potential conflicts occur over any fixes. A potential conflict between flight plans is defined as existing at a fix if:

a. the fix time estimates differ by 10 minutes or less, and

b. either flight plan has a VFR altitude at the fix, or

c. the specified altitudes, or blocks of altitudes, over the fix are separated by less than 2,000 feet.

The conflict search is carried out only for the specific fixes making up the flight plan route. The check is not made along paths between fixes. If a point in a flight plan is specified as a distance and direction from a stored geographic fix, the conflict check assumes that the flight passes over the fix. The check for conflicts is made whenever a fix time for a flight plan is calculated, recalculated, or corrected. To assist in this check, the computer stores for each fix a list of the flight plans incorporating that fix. Thus, whenever a fix time is calculated or changed, the computer can immediately determine what other flight plans are using that fix and can then check their times and altitudes over the fix. The detection of a conflict results in the generation of an output teletype message (see Section 3.1).

## 3.6 REMOTE MONITOR DISPLAY

A typical Remote Monitor Display is shown in Fig. 3-13. The features of this display are:

a. the plan position type of presentation showing geographical relationships as opposed to a tabular or flight progress strip posting

b. the "clean" display showing current position with a minimum of symbology and no extraneous information

c. the display of expected positions as an assist to short-range conflict prediction

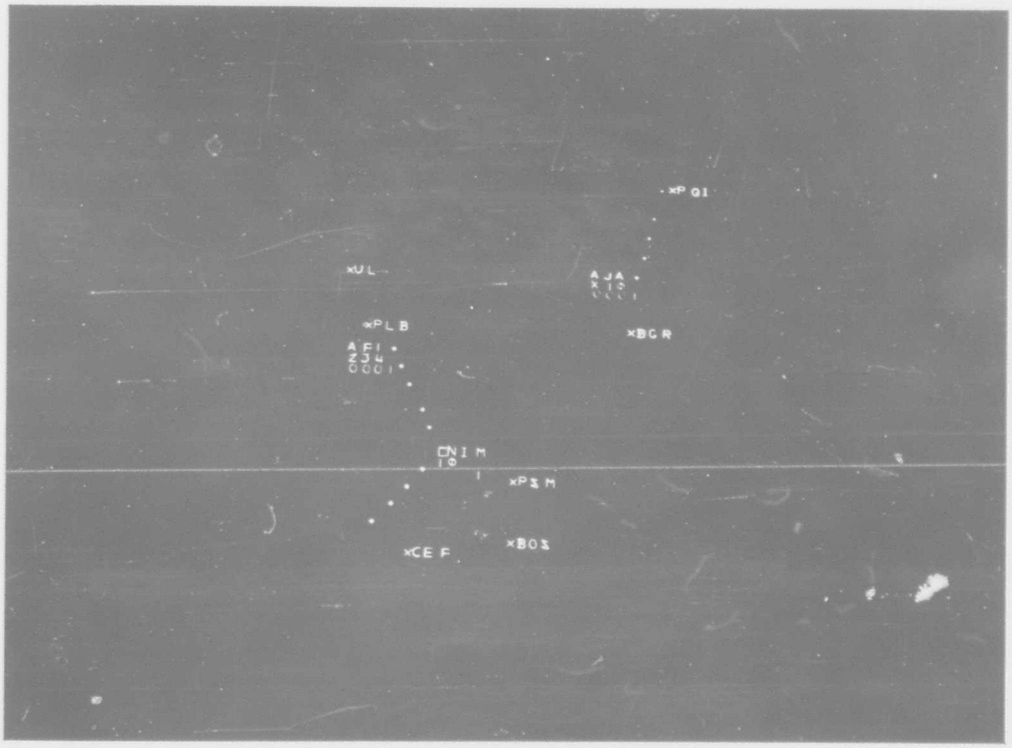


Fig. 3-13. Photograph of remote monitor display. The photograph shows the display of fixes (located on the scope by the symbol x) and the track messages for three aircraft, AF 1234, NIM 10, and AJAX 10.

The display is achieved by transmission of digital information over a telephone circuit to decoding equipment associated with the remote console. The digital messages, retransmitted once per minute, indicate the specific characters and the locations at which they are to be displayed. The display uses a 21-inch character-writing tube, with a selection of 64 different characters. The action of a direct-view storage feature of the tube results in a persistence which can be set to values of up to several minutes; by adjusting to a persistence with a sharp cutoff at about one minute, the once-per-minute message transmission results in a bright, flicker-free display suitable for daylight viewing. The area contained in the remote display extends to 180 miles about a center at 44°N, 71°W. As shown in Fig. 2-2, this provides coverage over most of the Boston ARTCC area. Present position is shown on the display with a square for a correlated flight plan, a dot for an uncorrelated flight plan. Expected positions at 2.5, 5.0, 7.5, and 10 minutes are shown by dots. Aircraft designation of up to seven characters as filed in the flight plan is displayed in two lines. A third line of symbology shows altitude in hundreds of feet or as VFR, depending on the filed flight plan altitude. A fourth digit in the third line shows flight size as follows:

a. no display for single aircraft

b. a single digit for flight size of 2 to 9

c. a + for a flight size greater than 9

A few geographic locations are shown, marked by an X and a two- or three-digit location identifier. The format for the remote display message is shown in Fig. 3-14.

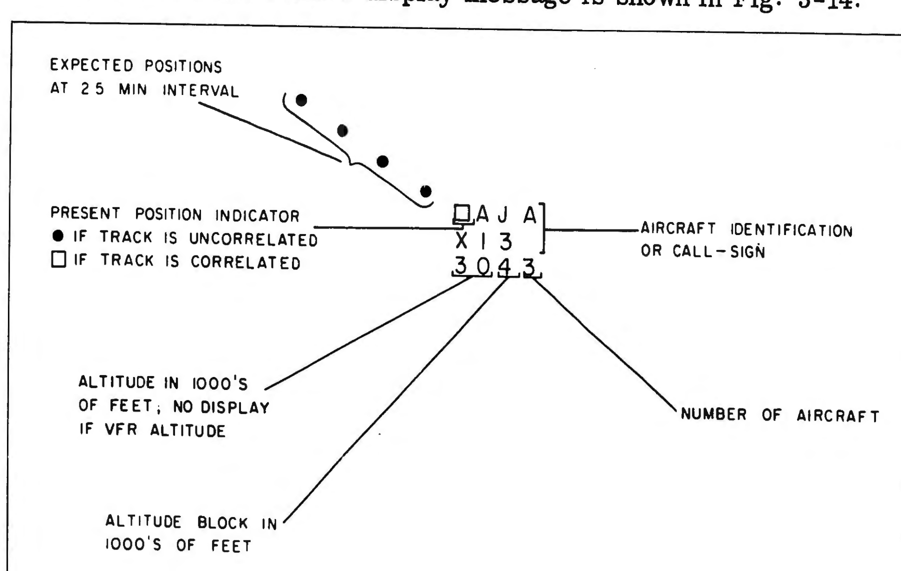


Fig. 3-14. Remote display format.

3.7 OPERATIONAL DATA RECORDING

An operational data recording feature is provided in CHARM to assist in system testing and evaluation. Flight plan data storage is scanned once a minute and the resulting summary data is printed out on a direct line printer. Summary data includes the time of each sample point and the numbers of active flight plans, code word routes, correlated flight plans (both search and Mark X), and inactive flight plans. The track monitor actions are also logged on the direct printer every six seconds. The computer thus provides the data necessary to accomplish system performance analysis and also to make detailed history studies of an individual flight plan. Fig. 3-15 illustrates the summary data recording. Figure 3-16 shows how TM actions are logged. In the example shown, the TM took action #6 (move to

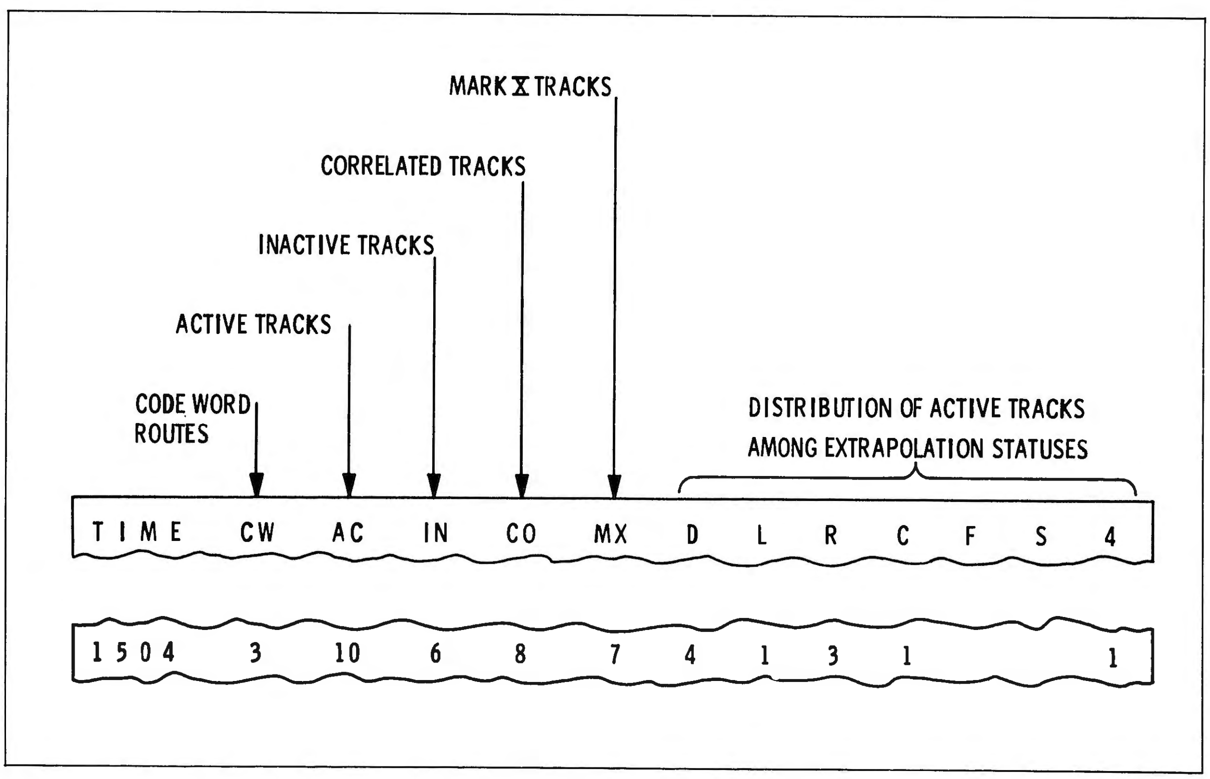


Fig. 3-15. Operational recording: summary.

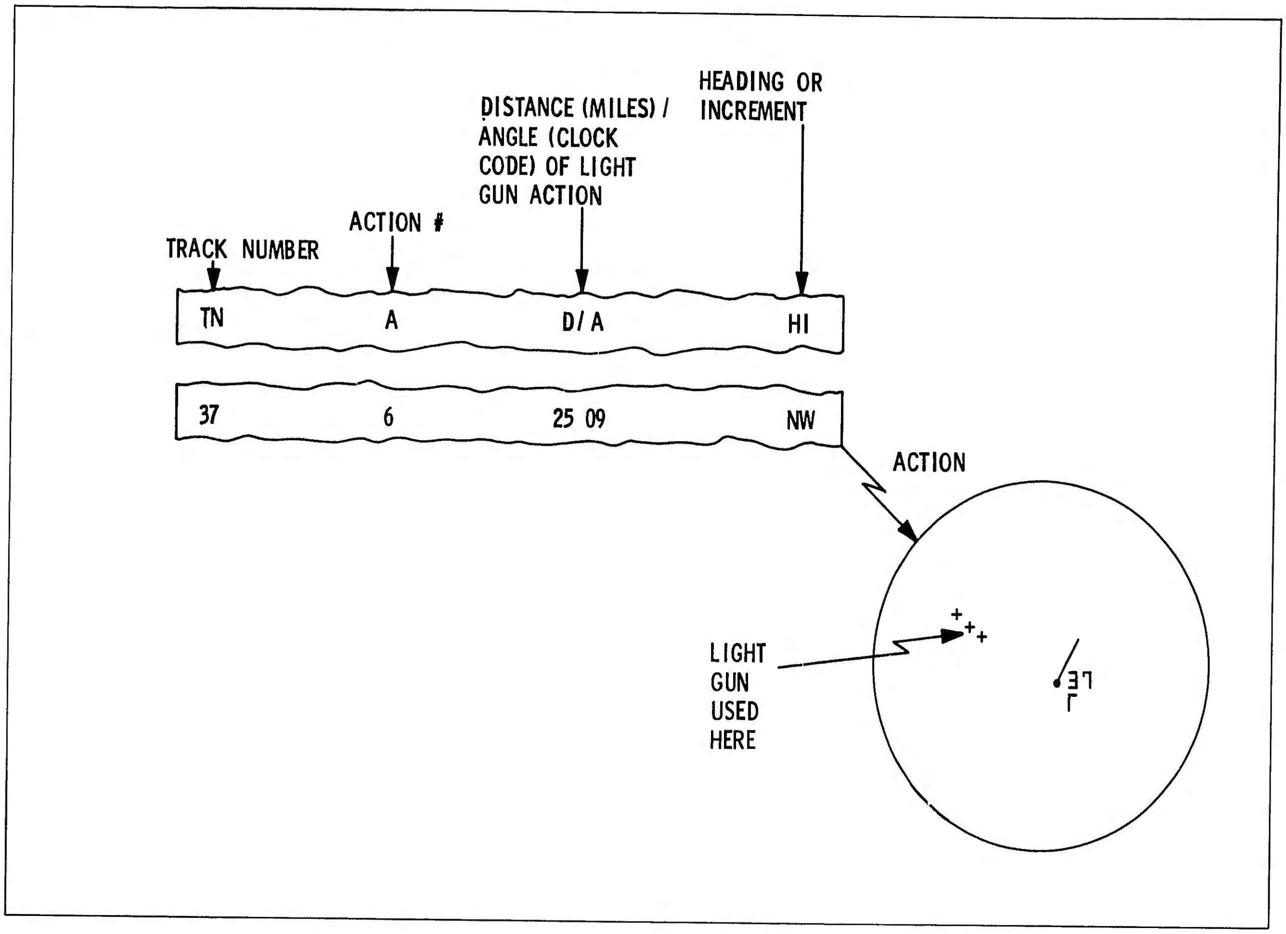


Fig. 3-16. Operational recording: track monitor actions.

radar data and extrapolate along command heading) on track number 37. The radar data was 25 miles at 9 o'clock ($270^o$ relative to heading) from the present position. The heading inserted was northwest.

## 3.8 COMPUTER AND COMPUTER PROGRAM

### 3.8.1 WHIRLWIND

The major features of Whirlwind are:

Random Access Memory (magnetic cores) There are six fields of core memory. Each field contains 1,024 registers (words), each consisting of 16 binary bits. Only two of the core fields are actively connected to the computer at the same time; the changing of these two fields is accomplished by a single computer instruction (change fields) in about 15 $\mu$ seconds.

Auxiliary Memory There are two rotating magnetic drums in auxiliary memory (AM): the auxiliary drum (AD) and the buffer drum (BD). Each drum contains 12 groups and each group contains two fields of 1,024 registers each. Of the 24 drum groups, 17 (or 34,816 registers) are available for auxiliary storage by the programs. The drums rotate at the rate of 1 revolution in 16 milliseconds. A total of 1,024 registers can be transferred from drums to core in an average time of 40 milliseconds (32 ms minimum, 48 ms maximum).

Magnetic Tape Memory There are five tape units connected to Whirlwind. Each tape unit has a reel containing 1,000 feet of magnetized tape. Tape is driven under the reading and writing heads at a speed of 30 inches per second. Each tape unit has the capacity of storing 160,000 registers, or 2,560,000 bits.

Input System

There are many ways of inserting information into the computer. The CHARM system uses the input buffer drum and insertion registers. The input buffer drum stores incoming radar data and teletype messages. There is capacity to receive approximately 340 radar returns from each radar site every six seconds. Buffer storage also allows for 255 teletype characters every six seconds. Insertion registers are used as an input to the computer from operating positions (such as track monitors). There are 30 insertion registers and two activate registers. Each operating station has a complex of buttons corresponding to specific insertion registers. The station also has an activate button that corresponds to a specific bit in one of the activate registers. The activate button is used to indicate that its associated insertion register contains input information.

Remote Output

The two remote output devices used by CHARM are teletype output and the remote display message output. There is no output buffer drum system in the computer. Teletype output messages can be transmitted at the rate of 60 words per minute. Remote display messages can be transmitted at the rate of seven per second.

Whirlwind Display System

CHARM uses four track monitor operating positions. Each of these positions has a situation display console on which the following type of symbols are displayed:

points (used for radar data)

\+ (used for Mark X data)

characters made out of any combination of line segments of a figure  ,

i. e., 2 3

vectors (used in general to denote speed and heading by means of length and direction of the vector )

### 3.8.2 PROGRAM STRUCTURE

The CHARM computer program is composed of various subprograms. There are 18 operational (or functional) programs plus the sequence control, timing, and startover programs. The sequence control program accomplishes all data and sub-program transfer within the computer. It exercises control over the operating sequence of the other programs. A series of tables is prestored along with the control program. These tables contain information about the operating sequence of the other programs and the sequence and location of all storage transfers (to drums and cores). The tables are used by the control program to provide the necessary computer environment needed by each of the functional programs. Tables are also used to designate any data required for program checkout, system performance, and evaluation. The sequence control program also accomplishes the transmission of all output messages. The timing program provides the CHARM computer cycle time of six seconds, the interval defined as a subframe. A counter of up to 10 subframes is maintained for those programs which perform a given function once a minute. The startover program is used to put the CHARM computer program into operation. There are two modes of startover: clear or continue. Startover clear is used as an initial start or as a restart in the event of a computer stoppage if the down-time is so long as to invalidate data storage. Startover continue is used to restart the system in case of a short-term failure. The philosophy behind the startover program is to prepare the computer storage for system operation. This entails clearing the input system (buffer drum and active registers), preparing the tables used by the sequence control program, and clearing drum and core locations. The remaining programs are broken into logical subroutines. For example, a radar input program treats incoming data, converting the radar data from R, $\Theta$ to x, y coordinates, displaying the data to track monitors, and determining if any track monitor has selected a particular piece of data by means of a light gun for some monitoring action. Another program prepares the output teletype messages, etc. The CHARM functions incorporated in the remaining programs have been outlined in previous sections of this document and are listed below in their operational sequence:

Radar input and display
Switch interpretation
Initial teletype processing
Input teletype decoding
Dynamic storage updating (from teletype input)
Output teletype makeup
Fix time calculation

Status and position determination

Position response makeup

Conflict detection or Quiz response makeup

Track monitor display

Remote display of flight plan position

Remote display of geography

Route display

Geography and flight plan channel occupancy display

Operational recording

Radar history display

Test recording

Subframe timing

## 3.9 DIRECTION-FINDING FACILITY

An experimental investigation of the usefulness of a direction-finding (D/F) facility is provided for in CHARM. This consisted of obtaining direct station-to-aircraft bearings for aircraft which are active in the CHARM system. Bearing information is sent by direct telephone line from the operators of D/F equipment at Otis and Westover Air Force bases to a D/F coordinator position at Barta Building. When the D/F coordinator has entered the bearing, together with the corresponding station and track number, by means of insertion switches on his console, a strobe display is generated by the computer. This display, available on selection to each track monitor, consists of a line emanating from the position of the D/F station and extending to the perimeter of the display area where the track number is shown. Figure 3-17 shows a typical D/F strobe display. This facility is intended to be useful in connection with radius flights where the flight plan has gone into suspended status and no position report is available to identify the associated radar data.

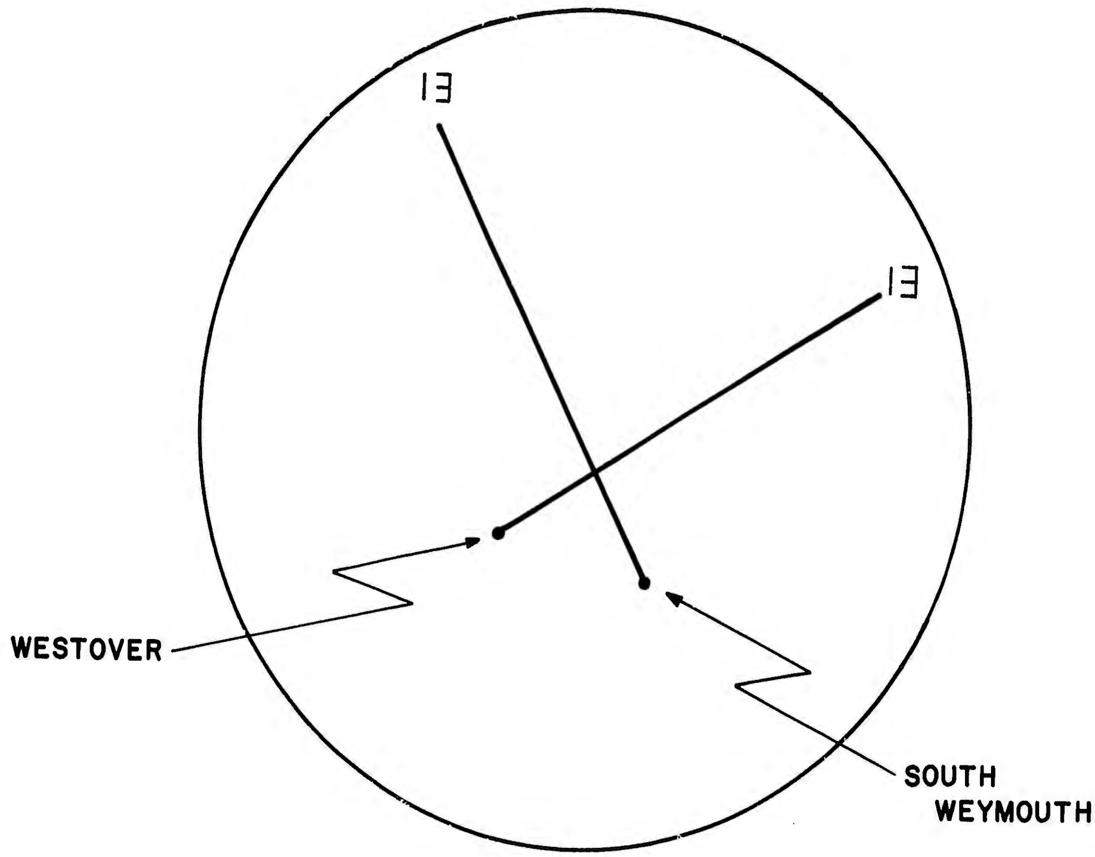


Fig. 3-17. Typical DF strobe display.

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